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Transforming Tensions in Learning Technology Design: Operationalising Activity Theory

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Abstract

Abstract: A brief review shows several suggested ways in which cultural historical activity theory has proved valuable to technology supported learning environments. Three of our own design cases are then described (evaluating a peer to peer interface for learning objects, designing an on-line school, and rethinking a public science centre). These are discussed to illustrate the approach and finally this is reviewed for potential re-use.

Résumé: Nous passons brièvement en revue certaines propositions, expliquant comment la théorie des activités historiques culturelles s'est avérée utile à des environnements d'apprentissage assistés par des moyens technologiques. Nous présentons ensuite des exemples de nos propres conceptions (qui permettent d'évaluer une interface d'égal-à-égal pour des granules d'apprentissage, de concevoir une école en ligne et de repenser un centre des sciences public). Ces exemples sont examinés en vue d'illustrer l'approche proposée. Finalement, nous considérons leur réutilisation éventuelle.

Introduction

There are several good reasons for learning technology designers to consider the social and organisational context in which their innovations will be integrated. This work begins on the basis that omission in this regard represents an overwhelming reason, in design, for poor matches with users' needs, misalignment with change policies and plans, confusions of roles and responsibilities in practice, and as a consequence, often very poor levels of technology uptake and use. In our own early studies (e.g., Dobson, 2001), for which evaluation models were based on reflective practice and the idea of a theory of action (Schön, 1987), many of the evaluation findings have turned out to be organisational in nature. The search for an operational method for identifying these issues in design appears to be crucial.

Activity theory (AT) seems to provide a descriptive language with which to look closely at the activity systems in which new tools are introduced. In this respect it is unique in its comprehensive approach to the elements that constitute human activity. Drawing from Vygotsky, the theory asserts that knowledge is mediated through the actions and interactions among those who use it. Thinking, learning and even knowing, are activities that are shaped by the activities in which people participate. Tools, structures and work-settings are created during regular participation in social activities. It is not possible to participate without inheriting the socio-cultural residue of antecedent conditions. Therefore cognition is inherently context and historically bound.

Moreover, the theory provides a way to understand how changes come about in activity systems through the reciprocal and unified processes of *internalisation* and *externalisation*. Thoughts, innovations and imaginations are the internal processes that can be manifested externally and lead naturally to new artefacts and social practices. What drives appropriation, and thus development, are the contradictions and tensions between individuals and socio-cultural influences, between two or more elements of an activity system, and between different activity systems. To "develop" means to resolve or transform these contradictions (instead of merely shifting them elsewhere), thus resulting in a change in the activity system: the construction of a new object or practice. Such a change is a long-term cyclical and spiral process of internalisation and externalisation that Engeström and Middleton (1998) call "learning by expanding":

> The essence of learning activity is production of objectively, societally new activity structures (including new objects, instruments, etc.) out of actions manifesting the inner contradictions of the preceding form of the activity in question. Learning activity is*mastery of expansion from actions to a new activity*. While traditional school-going is essentially a subject-producing activity and traditional science is essentially an instrument-producing activity, learning activity is an *activity-producing activity*.

Such a rich conception of social engagement in activity has provoked a series of investigative attempts to integrate AT into various design projects. Two recent special editions _ one in collaborative design (Redmiles, 2002) and another in computer-based learning (Morris & Joiner, 2002) illustrate this. The performative goals of these projects are diverse and include: organisational learning, collaborative learning, the design process, and the innovation process (not to mention various specific work activities). The value of AT from these projects also returned mixed results.

For some, the goal is organisational learning and the problem is how to analyse multiplayer learning situations. A recurrent issue is determining a principle for selecting a unit of analysis. Should it be the corporation, a team identified for some project, a procedure outlined for achievement of an agreed goal or some other? According to Virkkunen and Kutti, although the idea of an activity system as the "minimal meaningful system" for addressing that question is now attracting serious support, the emphasis on the temporal (historical) preconditions, goals and outcomes remains to be fully exploited (2000). They conclude that the activity system is clearly different and at least complementary with descriptive units of analysis such as routine, community of practice, or knowledge production (which they associate with other perspectives in organisational learning research).

Computer-assisted higher education researchers (Issroff & Scanlon, 2002) found that when used as a framework for evaluation, AT pointed to shifts in the activities needed to accommodate their web site among a traditional community of practice. They concluded that AT tends to "highlight negative features of the learning and teaching setting" and does not by itself lead to a balanced evaluation. They illustrate this by referring to an undergraduate class in which on-line resources were introduced and evaluated. They suggest the added value of greater access provided by web resources was not suggested by a focus on activity theory that led the evaluation to focus mostly on the tensions created by introducing this new material.

A number of projects have recently tried to create a reproducible procedure from AT for use in learning design. Mwanza (2002) for example, created an eight step process for analysing activity in workplaces, based on the component parts of Engestrom's (2001) model: subject, object, objective, tools, community of practice, roles and rules, followed by a review of contradictions and thematic tensions. They conclude, in the same way as Barthelmess and Anderson (2002) in relation to software design, with some frustration at the lack of direct prescription for designs that can address such tensions. In learning systems design this is especially important because of the often, mechanical use of activity theory to support any kind of collaborative learning design.

In the K-12 area Jonassen and Rohrer-Murphy (1999) produced an excellent prescription for designing cooperative (constructivist) learning environments based on activity theory. Although this work does not reconcile the idea in activity theory, that consciousness (and learning) depends on activity, with the dualism of criterion-referenced design, the work does provide an unequalled framework for analysis. They add the idea that procedure, routines, operation and action are subcategories for activity. In fact, as might be expected from the focus on sequenced competences, their goal is to link activity structure with traditional instructional design and activity theory.

In work concerned with the embedding of new medical diagnostic apparatus (Miettinen & Hasu, 2002) AT is used to show how an innovation can be seen as culturally bound. They show the development of separate, potentially converging networks, during the process of recognising need and the potential for some innovation (new tool) to play a role in better practice. However, they say, the framework is general and does not prescribe any solutions. It is valuable only when people start to analyze their work practices by using it, relate the abstract model to concrete facts about their everyday activity, give meanings to the elements and their relations and change their work, themselves.

These examples of past research show that activity theory attracts significant interest, is open to many interpretations, and in reflection on its use, has precipitated both positive and mixed reviews. All these reports appreciate the value of AT to broaden the design goal, but two criticisms remain common, namely that (a) the descriptive ethnographic-like emphasis in most AT studies does not (and possibly should not) lead to clear design prescriptions (e.g., Barthelmess & Anderson, 2002; Miettinen & Hasu; Mwanza, 2002), and (b) the focus on tensions and contradictions does not naturally lead to a balanced assessment (evaluation) of an innovation (e.g., Issroff & Scanlon, 2002). This paper will illustrate our own initiatives in this area and conclude with an effort to explain how these criticisms do not reflect the potential for AT to positively affect design of learning technologies. The case studies here illustrate three methodologically different ways that the theory can be successfully used. In case one, the role descriptions in the target user activity group helped us to design the user trials while creating new software. Case two describes how the explicit consideration of roles helped manage operational meetings. And in case three, we show how the discipline of considering activities in a large public space generated improvements both in redesignation of roles but also in the physical layout of installations within a public science centre.

Evaluating a Peer to Peer Learning Object Repository Interface

One promising opportunity for the operationalisation of activity theory lies in the context of evaluation, and for our purposes, in the improvement of designs (or formative evaluation) for technologies to support learning. We see that understanding the activity systems in which these new technologies are introduced is critical so that the technologies have some chance for successful integration. In this way the learning objects and their support tools represent a change in the mediating technology that subjects (in the sense used by activity theorists) use to act and achieve their object of intention. This is the approach taken to evaluate the interface to a distributed learning object metadata system called SPLASH (Richards & Hatela, 2002) and its related tools and standards for sharing learning objects. The method of evaluation is influenced by a utilization-focused approach (Patton, 1996), which drove an interest in the many kinds of interested parties that would benefit from the results. We were committed to finding primary intended tool users, those the project backers would recognise as users of the research and with a vested interest in the findings. Activity theory is similar to Patton's (1996) approach to evaluation in its emphasis on the participants (as well as tools, goals and so on) that constitute intentional action. In drawing from both sets of principles the evaluation identified the participants within the activity system of intended use as significant primary evaluation users. We began by outlining the activity systems for the proposed software and correlated this with the feedback on the beta-test prototype software in the following way.

The SPLASH tools are designed and developed to meet both an increasingly clear user need, and also to provide function and service to users that has so far been generally uninvisaged at the operational level. These tools are described in detail in other papers by Richards and Hatela (2002) and a screen shot of the search interface is given in Figure 1. These are early efforts; the business of learning object development is only recently becoming organised and the opportunities are still not well understood (Porter, Curry, Muirhead, & Galan, 2003).

Around the world, large, unconnected and disorganised accumulations of earlier activity remain unknown to the wider higher education system, unused even in local context and unexploited by the global learning object enterprise. The reliable and well-organised storage and indexing of learning objects will be a benefit to a significant range of professionals involved in learning and education.These tools represent a major part of the infrastructure needed to achieve a steady and productive flow of activity in a rethought and redesigned system for higher education in the future (Laurillard, 2002). These tools are immensely important because, on the one hand they will enhance the economic stability of the activity, and on the other, will shift the roles, expectations and performance implications for those engaged in the enterprise. It is important therefore to understand the current activity systems - the priorities of interests, the affordances of tools, their intersection with rules, roles and communities, and what effects are likely from introducing the new tools associated with learning objects.

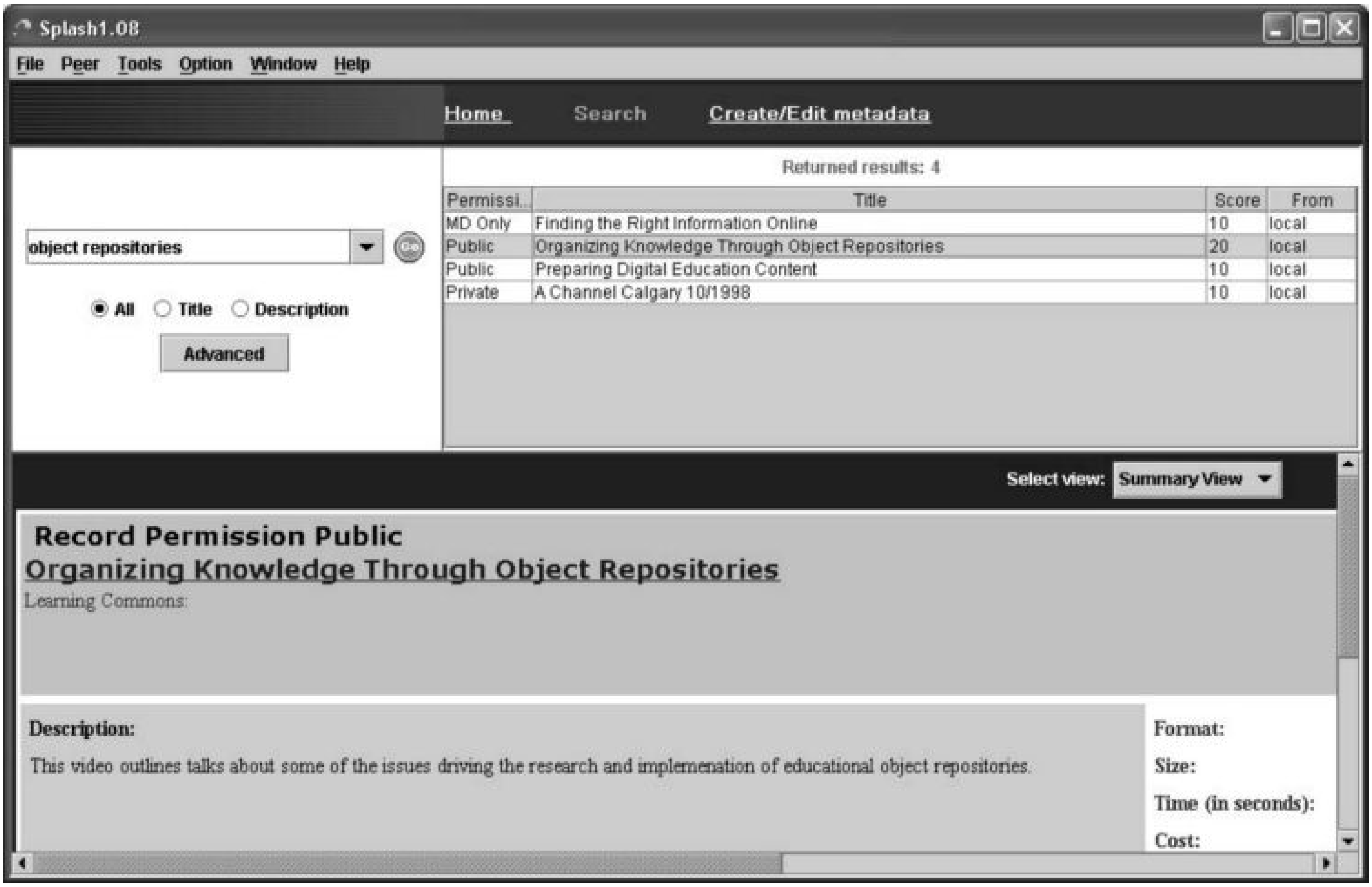

Figure 1. The search interface for SPLASH.

To evaluate SPLASH we first conceived a plan based on stakeholders' interests, justifying data collected against reasons for evaluating, focusing on particularly prevalent issues, and planning for opportunities in the development process. Such a method has been outlined carefully under the RUFDATA rubric (Saunders, 2000), has been used in other evaluations since (Dobson, 2001) and is consistent with Patton's (1996) utilization approach. The evaluation results were to be used to validate the successful completion of the project work, drive the next stage of research activity and to assess the possibility of exploitation and integration. In practice the evaluation identified a number of foci that can be understood from the users' point of view:

1. Validation of expected functionality: Does it do what was planned?
2. Usability _ particularly in creation & search: Can users do what they need?
3. Differences among user's experiences with meta-data: What variety of needs exist?
4. Fit with activity workflow: How would it fit with current work practice?
5. Potential for integration: What is the likelihood of adoption?

To address these goals a study was designed in two parts involving five participants with strong roles as: designer, assessment coordinator, librarian, instructor, and media developer. Simple generic tasks (searching and retrieving) were executed using the tool while users described and attempted activities relevant to their typical work practice. Users were observed in action executing the task and followed by a series of predefined post-task questions. These partly co-constructive interviews (Knight & Saunders, 1999; Lincoln & Guba, 1985) were recorded and transcribed to form 75 real-time minutes of dialogue.

The second part looked at how participants with roles in learning object activity are supported or otherwise affected by SPLASH. Each participant accepted an invitation to a follow-up focus group. After considering the roles and interests in learning object activity we continued to project the affect of the SPLASH technology on the working group. Because each role participates differently we therefore first elaborated the interests of each role and then considered the benefits and any limitations of the SPLASH architecture in providing a common communication and general sharing environment for those players to communicate.

Results

Both the importance of the problem addressed and the general design were acknowledged highly by all participants. The tool was considered recommendable to other users and many of the interface design styles were regarded as usable, innovative and consistent with contemporary standards of interaction. We noted minor problems of user response to the adopted metadata tagging standard, the relation of that standard to the full range of learning objects and to the interests and needs of all those involved in the learning object related work.

Each of the participants were employed in a high-tech university and are good examples of these roles. The results in this area reflect mostly on the range, depth and selection of elements within the mark-up language that is supported by SPLASH. These reflections reveal the major pre-occupations of the users likely to work with SPLASH and the kinds of functions that need to be considered part of the overall activity system in which SPLASH will be used and should integrate. By working with the informants in assessment of the tools in relation to their priorities we were able to form an initial prediction of the introduction of SPLASH in workflow.

Overall, we found by looking at the roles and pre-occupations of those who will use SPLASH, several questions emerged about how it will fit. Several roles (we noted designer and assessment co-ordination) will want to use SPLASH to learn about other's previous efforts. This tool is not a case-based learning system like others described around knowledge management and activity (e.g., McCalla, Greer, Kumar, Keagher Collins & Tkatch, 1997; Schank, 1996), there is no automation, and the reliance on the appropriateness of the ontology is very high. We also noted that while some of the data components needed for activity around objects are included (e.g., copyright information) in SPLASH and CANCORE, that these by themselves do not add up to a transactional model for managing exchanges among players. This is crucial because an open-access model with no such economic framework would suggest a distinct shift in the roles of academics and instructors, their authority over their own professional practice and so on. We also noticed that the options for describing pedagogical assumptions were limited to the needs of fairly traditional instructional designs, and that for learners we would expect the need for associated tools to integrate related areas of the learning architecture, e.g., credit transfer and program construction.

Creating and developing shared ontologies for communication within team based activities is an inherently problematic and even political process. The power of tools for supporting performance and the risks to outcomes both lie in this area (Randall, 1995; Suchman, 1993). Users working with the CANCORE metadata tags, particularly during the creation of data, but also in search-mode, experienced significant confusion about what data was required for many labels. Two of the five participants identified learning objects for meta-data creation that proved difficult to characterise usefully in the framework. One object, a prototype web-mail tool, had been used as an exemplar environment in a module meant to prepare learners to design and create on-line environments. The concepts of coverage, relationship-kind and meta-meta data, as examples, caused universal confusion. In fairness, for simple learning objects, once the dimensions of coverage are explained, the required information can be easily added. For example, a grade-ten citizenship module could easily be constrained by the country in which the details applied and the dates that material is relevant. In contrast though, for the prototype webmail software, there are no particular content descriptions, no pedagogic features and no catalogue entries.

A principle of learning object reuse lies in the potential to identify parts of objects that can address the interests of new object developers (Wiley & Edwards, 2003). The range of metadata in CANCORE may unfortunately represent a declining or skewed model for what might constitute the full range of learning objects. From the emphasis on cataloguing, on concepts like coverage, and because of information provided in the guides (CANCORE, 2003) there seems an emphasis at least on a particular kind of object. Objects normally provided by educational and training organisations fit well into the format while learning objects developed for performance support tools to facilitate communication without easily described content present a challenge. Such observations appear to be relevant as much to other standards models such as IMS (2003) as they are to our own Canadian models.

Another concern lies at the heart of the co-operative and collaborative nature of interaction suggested by the activity theoretic analysis. The data shows the metadata tags may not optimise support for needs and interests of the full range of roles involved in the learning object enterprise. In our study, guided by both activity theory and utilization-focus, we deliberately spotlighted the practices of our prototypic role players. For the assessment coordinator, her need was characterised very clearly.

> My particular learning need is related to the maintenance of a quality of relationship between the assessment instruments and the materials developed and delivered at TECHBC. This means I often need to look for independent assessment instruments for comparison or for use. In general I am also interested in techniques used for assessment as part of my professional research toward ensuring we are recommending the right kinds of things to our faculty.

In addressing this worker's need the tool was invoked in a series of ways. First the user sought objects that could be of interest in terms of content. Together we looked for modules that dealt with statistical analysis techniques and experimental design. Then we looked for modules with content dealing with assessment techniques. A module emerged that described, in the description field, an assessment technique used within a module (the content of the module was of no interest to the searcher). This highlighted for us that there was no way to identify the assessment approach taken by any object and indeed no object type representing assessment objects. For this user it would be very difficult to achieve her goal using the current metadata framework. This tension is labeled 1 in Figure 2 below and is followed almost as direct consequence by the tension labeled 2 that shows the community of practice is also in tension with this particular tool (since at least one role player is not supported).

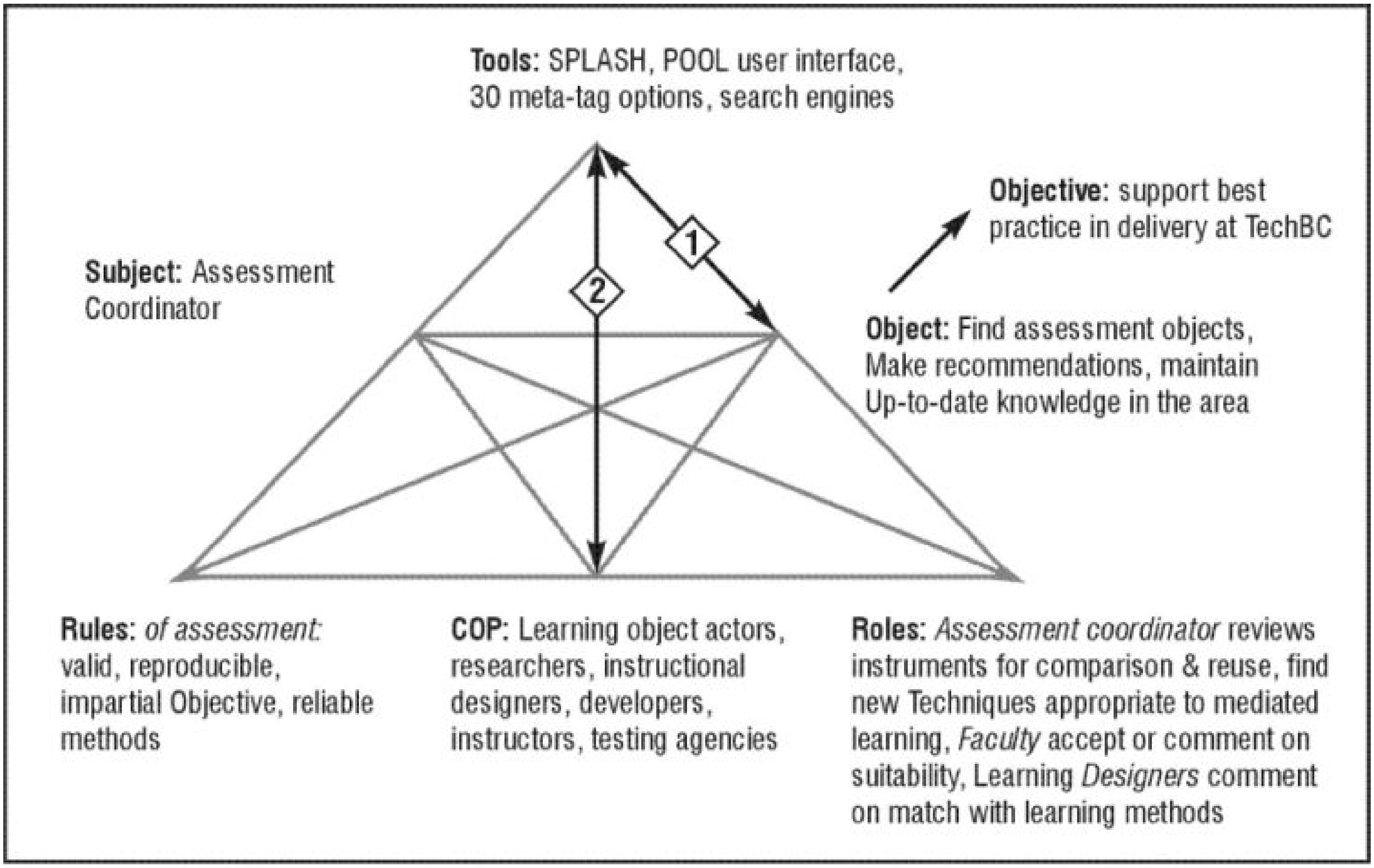

Figure 2. SPLASH, CANCORE and the assessment tag (evaluating a new tool in context).

The librarian described their goal in this way:

> My particular interest is in educating the university community about learning objects. I need to achieve buy-in. We will likely use a similar technical solution (to SPLASH).

For this user his goal was to demonstrate the benefit to regular university academics in using a learning object model. The user described how two years ago his job description had been written in terms of learning object search. Immediately after starting his role he had conducted a search in cooperation with a faculty member that lead him to a re-usable component that is now used as part of the university's regular delivery. He continued to describe how this was one of the last times that the activity was undertaken. He believed that there were too many instructors for this form of search to be done regularly. He also indicated how he saw his new role in creating tools to support the process of learning object tagging.

This story indicates several tensions that can be represented using the activity notation and are pictured in Figure 3. Although the user's initial work description outlined the recurrent practice of object search there appeared to be no direct impact from low levels of implementation or returns on search (tension 1 in Figure 3). The allocation of effort among players was not aligned with any definition of the work object that required the effort was successful (tension 2 in Figure 3). The finding and use of objects was not tightly linked to any performative description of a learning object. The re-use of objects is seen as an enterprise goal to support cost-efficiency. In this activity system there are no cost-efficacy objectives described and therefore no means by which object creation could be normatively measured or assessed (tension 3 in figure 3). Interestingly, the informant seemed quite aware of these tensions and offered his own transformation, namely that better tools were needed so that instructors/designers could do their own searches for learning objects. That solution would of course (without careful consideration) likely lead to new tensions probably at least changing the division of roles between the librarian and the instructor.

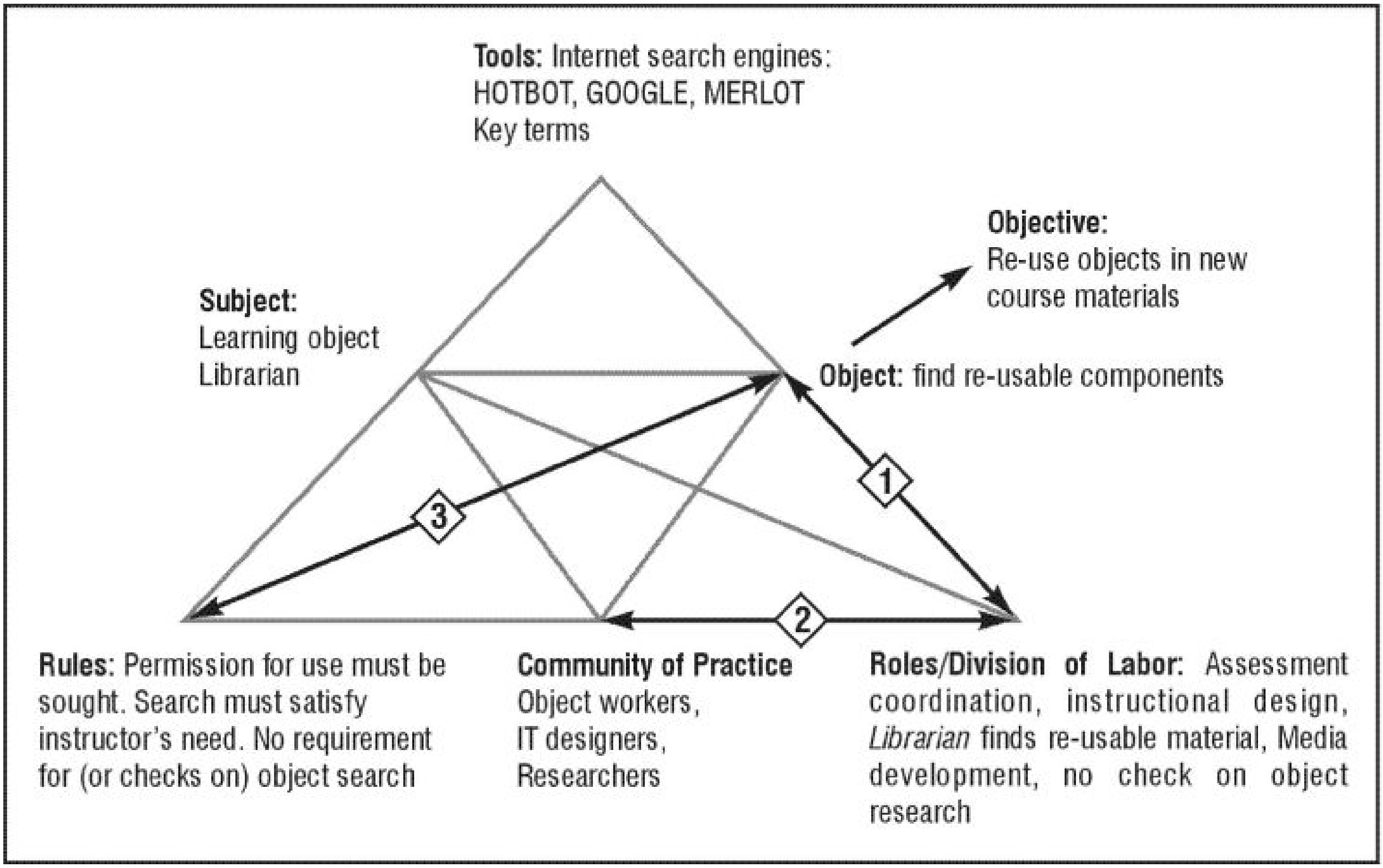

Figure 3. Tensions in retrieval of learning objects (identifying design requirements).

Discussion of Splash Evaluation Findings

The principles of activity theory suggest a different approach to instructional design that affects both what we might expect from a tool like SPLASH and how we should expect it to be used. In Engestrom's "boundary crossing workshops" (Engestrom, 2001) we see a prescription for action designed to achieve learning goals. That process achieves performance improvements by first locating the perceived performance problem then assembling the groups involved in the work systems and helping them to communicate (mis)conceptions among each other. This is very different to traditional instructional design approaches where it is assumed that the learning outcome is known prior to the course development. The general approach has much in common with other situated learning theories (Brown & Duguid, 2000; Collins, Brown, & Newman, 1990; Wenger, 1998). By itself activity theory suggests a form of learning object that would be very hard to capture within the meta-data format outlined in CANCORE.

The activity theoretic approach helps to illuminate the organizational social and cultural conditions in which tools are introduced. Our subjects in evaluation may appear unusually willing and receptive to the tools _ indeed they do not work in traditional universities where changes implicit in the use of these tools are much greater. In this area Freisen (2002) recently cited Fensel as follows:

> The goal of increased interoperability both within and between communities will clearly not be achieved through further formalization and abstraction. What will bring this goal closer is increased negotiation within, but especially between

> communities. If interoperability is to be established between educational communities or across a semantic Web of disparate resources, it seems likely that organizational and descriptive rather than technical supports are the key ingredient that is currently lacking. (Fensel et al., 2001).

In summary, the same kinds of organisational and knowledge construction constraints that exercise opportunity and success while introducing CSCL technologies will also affect the introduction of peer to peer repositories and their interfaces. Blacker's (1995) work in this area demands we understand how knowledge is embodied in the physical behaviours and settings of the workplace; what is embrained in memories and intellectual resources of the practitioners; what is encultured in the expectations of social practice, beliefs about the appropriate regularity and nature of key activities; and which knowledge remains encoded in the documented boundary objects. Furthermore the culture of an organisation will also affect opportunity. Cultures dominated by factions, coups and challenges to leadership, as well as those that adhere strictly to predefined roles and behaviours are less amenable than where service to the client is most important, where hierarchies are shallow, and where achievement of goals is highly regarded.

> The conversion of data to information or knowledge that happens in the interpretive process of metadata creation implies a number of commonplace social and human realities: It entails personal involvement in and commitment to specific practices, and participation in a community of those with similar or complimentary understandings. [] the significance of words and descriptions in metadata may not be so much a matter of clear and unambiguous definition — as one might be led to believe from the highly technical orientation of many metadata specifications. Instead, it is more a matter of doing, acting, and belonging (Freisen, 2002).

In practice, our design processes must capture the relationship between information that is contained in the meta-data (or is at least currently proposed for inclusion) and other reifications of process and the different interests of those engaged in activity related to those objects (in our case learning objects). The current meta-data format for CANCORE includes over thirty-five tag names - too many for users to work with in an undifferentiated user interface. These may have been arrived at without first understanding the particular needs within the activity system. To be clear _ we think the goal for multiple role user interfaces is to support the needs and interests, and to trade off the conflicts of usability among its users. Beyond that we need to be aware that people with different roles communicate within groups. They will use SPLASH as an interface to a complex common ontological environment that has to be negotiated in practice by practitioners.

Designing a K-12 Virtual School in British Columbia

In the previous example we showed how activity theory could be used to analyse the context of integration in terms of representative users' actions in order to presage the needs of users and plan a technology solution that leads to a holistically functional system of activity. In this subsequent project we used the tenets and tools of activity theory in a rather different way. In this case Engestrom's (2001) triangulations (examples in Figures 2, 3 & 7) are used as a means to focus and coordinate the efforts of a team charged with implementing a distributed learning program in British Columbia.

Implementing a distributed learning program in a local school district presents significant challenges. Distributed learning is still a new phenomenon in school education and designs tend to be pragmatically driven. Individuals hold disparate assumptions about both the goal and the method. Four years ago, one of the authors developed our first online course, a Java programming module for secondary students. An online design was chosen because of teacher shortages in the Java language and small numbers of students in each school. The experience proved that students from across the district could be united to learn effectively in a distributed setting. Administrators began to consider other areas. Two committees were formed to look at possible applications. One consisted of district administrators and individuals with leadership positions and was charged with investigating Internet tools to support Professional Development. The other constituted two administrators and the designer of our Java course. A new principal was hired from outside the district. He had extensive involvement in the establishment of a virtual school in the nearby province of Alberta. A proposal was made for the establishment of a new virtual school in BC that was accepted and then the team began to act.

The virtual school design was initially modelled directly on the Alberta program. An agreement was reached to purchase content and a server preconfigured with a management system. Teachers from the local district would be paid to modify the existing content to meet with British Columbian standards and to develop new courses where needed. The proposal focused on financial issues such as how the program would become self-sustaining by attracting new students to our district and retaining those whose needs where not met by traditional instruction.

As a result of legal negotiations with the Alberta virtual school, the team met only occasionally to discuss implementation and those meetings were often unfocussed. Different individuals had early access to information (either because of their role in negotiations with the initiating group or their responsibilities tied to the original proposal). Individuals held varying assumptions about the program design, how to develop it, and who would be the expected audience. Some, who would ultimately assume key roles in the virtual school's development and delivery remained on the periphery. Figure 4 represents the flow of information between key members of the implementation team. The size and direction of the arrows indicate that most of the current interaction has been among the district's Technology Coordinator, and the virtual school's principal and vice principal. They submitted the proposal and have been involved in negotiations with Alberta school. The principal of Alternate Programs and the online teacher/developer come together bi-weekly with the others to work on the implementation plan and together form the key members of the team. The Assistant -Superintendent is appraised through the District Technology Coordinator and the principal of the proposed virtual school. There are many communications both informal and formal that result from overlapping responsibilities amongst the members of the team.

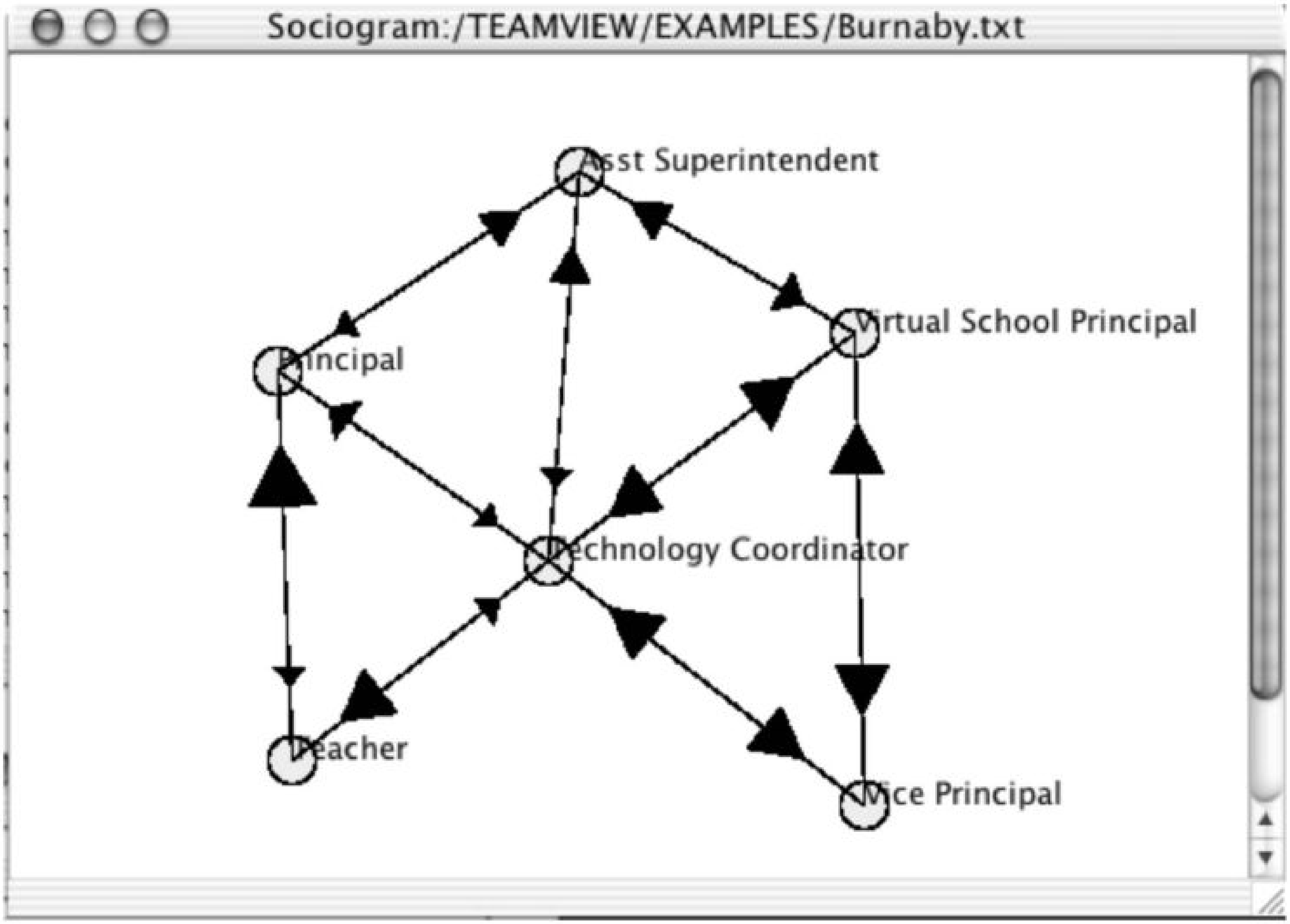

Figure 4. Network of actors in the virtual school implementation team. Created with TEAMVIEW

With such a broad range of duties and processes there is plenty of room for misunderstanding. Discussions dealing with implementation issues have not been the priority and some team members have expressed concern over a lack of resolution in the meetings. Agendas have been left unaddressed and discussions meandered as new points of concern arose.

As a response to this we introduced Engestrom's diagrams as a framework for mapping the various components in the activity system. As the diagram was circulated we suggested that we use it as a tool to help scope issues needing to be addressed and to identify the various individuals involved (see Figure 5). We suggested concentrating effort on defining individual roles as well as the roles of others with latent involvement in the project. The activity system diagram certainly helped. When divergent topics arose we would list these down in the appropriate section of the chart as part of a continuing agenda development process. This helped alleviate anxieties that important points might be missed and provided a reason to include the roles and names of individuals who were not previously discussed and who were unknown to some of the team.

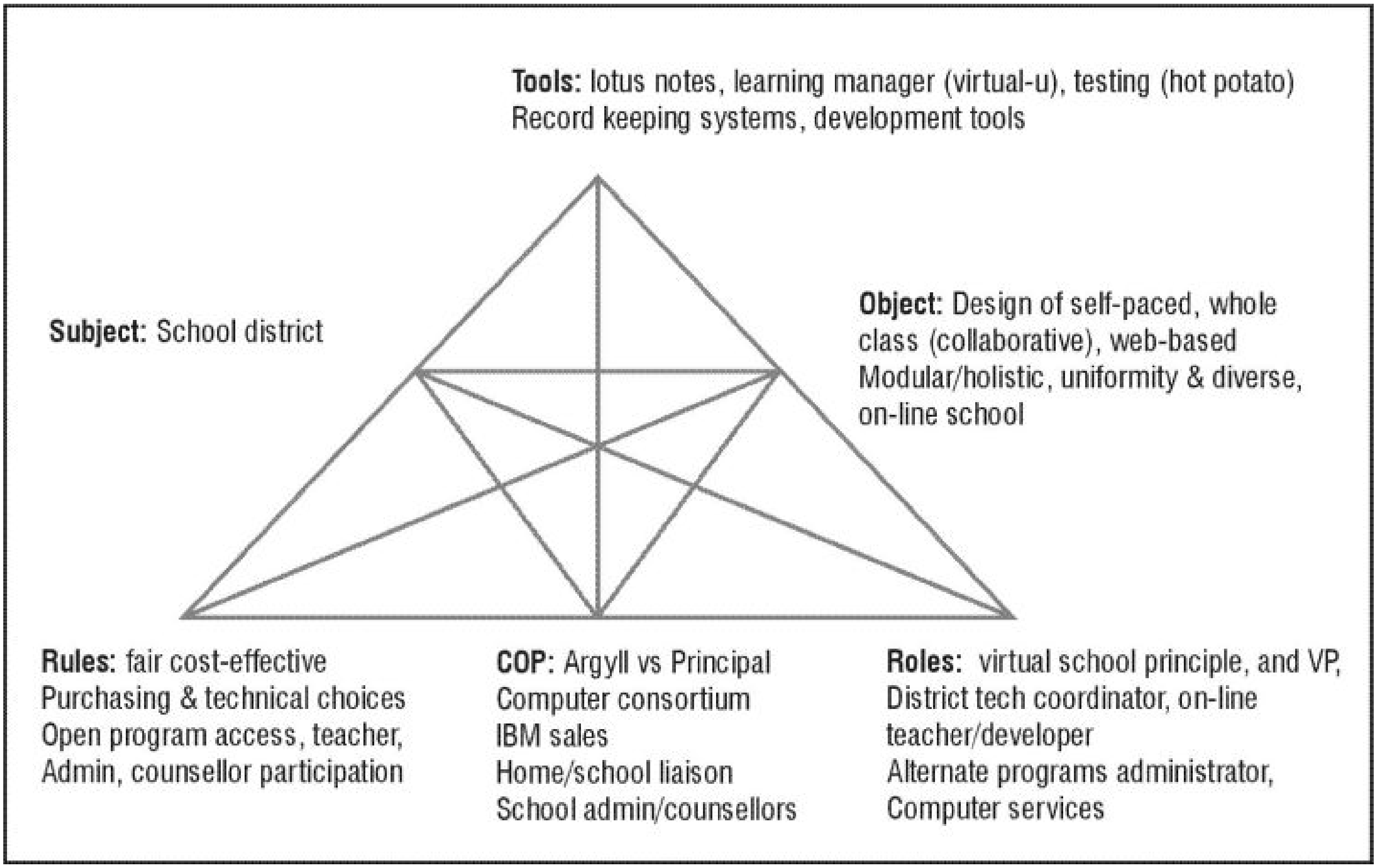

Figure 5. Creating a virtual school in a lower mainland school district.

The diagram helped anchor discussions and situate action plans. Misalignments or contradictions in the activity system were frequently negotiated as they became illuminated through our discussions. Some of these contradictions stem from the misalignment of goals and motives amongst different members of sub-activity systems. The virtual school administrator held an understanding of what the courses would look like and how they would operate based upon his past experience with the Alberta virtual school. This model is structured around learners working independently through lesson content while communicating with their teachers through email and telephone contact. Lessons consist of interlinked web pages interspersed with fill-in-blank worksheets. The program envisaged relied heavily upon parental involvement to maintain learner focus and monitoring of the pupils' progress. Very few of the initial courses included lessons that encouraged student-to-student collaboration and communication. One of our objectives as designer and the teachers' trainer is to maximize opportunities for dialogue and human-to-human interactions. Our research and experience as a classroom teacher have convinced us of the instructional benefits in adopting collaborative learning practices.

Through ongoing discussions a constructive solution was found for the direction of the instructional model for the virtual school. The benefit is now clearer for offering individualized, learning packages to those students entering our program at various starting points. The virtual school administrator has a better appreciation for the potential strengths that collaborative learning practices can afford a distributed program. The team decided upon a parallel development plan. The primary focus will be directed toward collaborative whole class instruction with contingencies in place for alternate or individualized pathways through instructional content.

However, although this is the agreed design, the integrated templates of the learning management system we have acquired from the vendor do not reflect these principles. This represents a significant contradiction in the appropriateness of the tools used to modify, develop and deliver our courses. As the teachers' trainer, the designer is charged with facilitating and encouraging a best practices approach within the distributed environment. While the existing tools have the potential to support whole class instruction they are not currently structured to do so. Budget and time constraints limit our options for the adoption of and transfer to more appropriate tools. A possible solution to this dilemma will be to engage the teacher/developers in collaborative development activities that will explore work around measures to overcome the tools' limitations. Ongoing dialogue within development teams should foster a shared understanding for the goals and expectations of the program. Using the development tools and our learning management system to host these collaborative, discursive activities will provide the teachers with practice and a greater appreciation for the limitations and potential of the tools.

Figure 6 depicts the misalignment between the virtual school administrator's vision of the instructional program and the vision of the designer and teachers' trainer. Early organisational meetings of the project were held with the administrator, technical coordinator and promoters. This arrangement initially supported decisions about delivery that were later found to be in tension with the instructor/ designer's preferred goals and approach. This is shown in Figure 6 as a tension between the assumed roles and the shared object (tension 1). Although this tension was transformed through dialogue and mutual perspective sharing until the point where everyone in the team recognized the benefits of both forms of delivery (collaborative and preconceived), the templates constructed and purchased by the early project leaders are really designed for use in non-collaborative instructional designs.

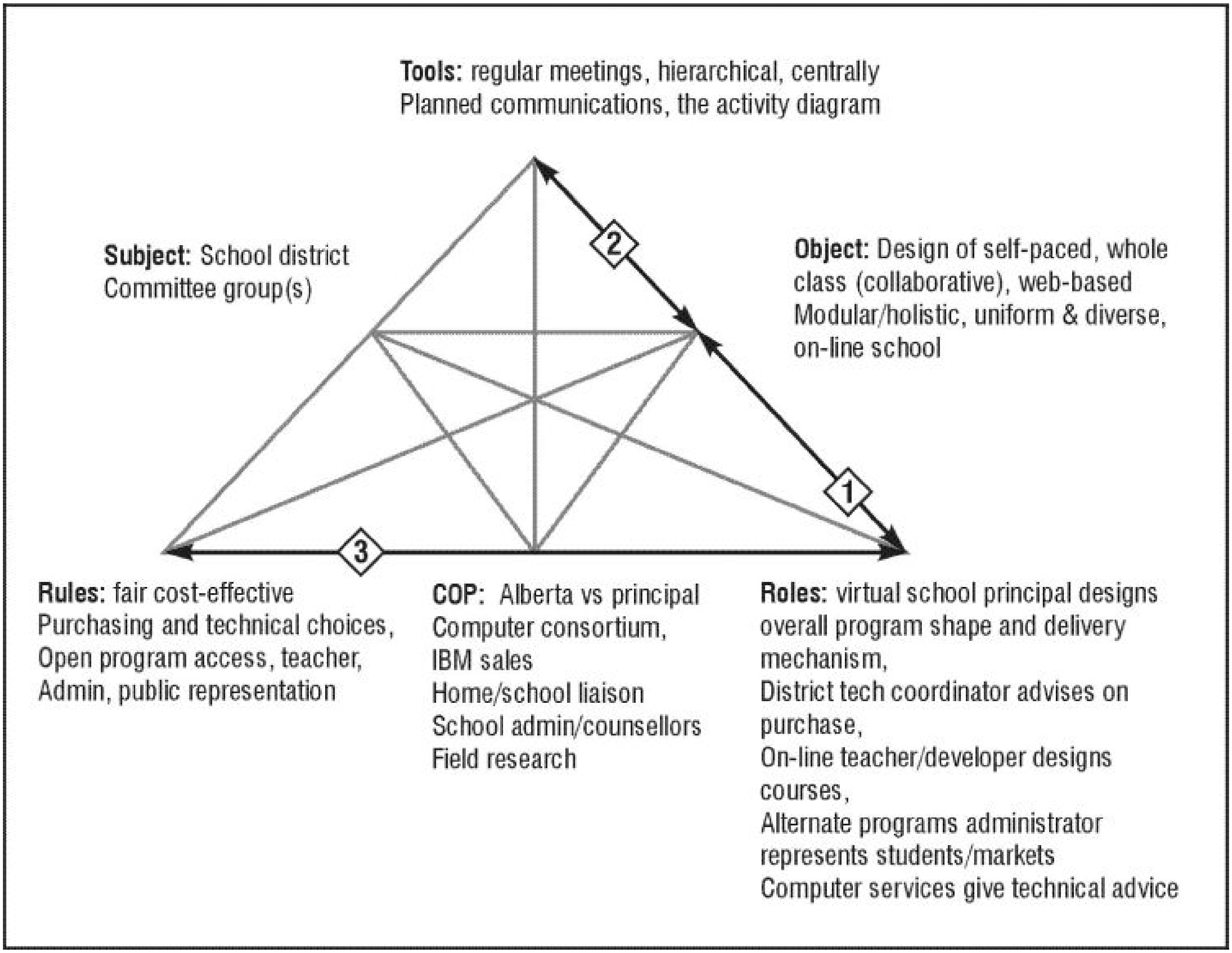

Figure 6. Visions of design for the Virtual School (using Diagrams to manage workflow).

This leads to the second tension between the activity system tools and the stated and mutually agreed objective for the group (tension 2 in Figure 6). This controversy over participation in the design activity also led to (or was at least paralleled by) tensions between the teacher/developers and their community of practice, namely the local teachers' union and their classroom-based colleagues. Claims were made based on general rules of fairness in the process of change toward new methods of teaching and learning.

While administrators (with support from commercial/technical sources) make decisions about global delivery, they perhaps unwittingly, affect the options for teacher designers to implement their best practices. In the bigger social context this translates to concern from the teachers' union that online teaching will take away classroom-based teachers' jobs (this is shown as tension 3 in Figure 6). The teacher's collective group has been unsupportive of the initiative and argue it opens the door to defaulting on agreements. The team counters that the new program will attract new learners to the district while retaining learners who often leave when traditional delivery programs fail. There are therefore at least two discussions taking place, one really about student numbers and working conditions, and the other about changing practices. Both are real, but as the diagram illustrates, the transformation of that tension which is focused on quality of outcome can occur when timely involvement of informed teacher/designers are involved. The quality of the delivery depends on the voice of the designer, not the administrator or the teaching union representative, who are both concerned with other related goals.

Helping Visitors Get More From Science World (Facilitators)

[1] Sharing much with cognate venues around the world, e.g., *The Exploratorium*[2] in San Francisco and the Explore center in Bristol, UK[3] , *Science World* in Vancouver is a hands-on science centre welcoming adults and children to the excitement of discovery. It is run as a not-for profit organization and raises over 90% of its annual operating budget, the balance generated through grants, donations and special events. The mission statement illustrates the energy and excitement of this world-class center. *"Science World is a vital, non-profit community resource that celebrates curiosity, creativity and the thrill of learning by promoting exploration of the arts, science and technology."*

In this case activity theory gives us a way to think about opportunities provided for interaction. By emphasizing the expectations for action, the signs, symbols and practices of participants, and the goals of activity within a social context, activity theory helps to explain and optimize the activity and dialogue design. The method used in this project is then different again to the either of the preceding cases. Here, instead of focusing on evaluation or operational practice, we are concerned more with the generation of new options for interaction design.

Like many informal educational institutions, Science World is set up to facilitate a constructive learning process by creating a rich juxtaposition of scientific phenomena and information within an enriching and socially supportive environment (Falk & Dieking, 1995). Learning occurs when learners engage in the planned opportunities for discovery, using hands-on activities and exchanging their ideas, with their companions, parents or staff from the center. The experience is fully immersive; the multiple forms of mediation and representation present a richness of experience that no school or home could ever offer.

From the compelling architectural structure, to the visually appealing and carefully designed exhibits, to the items offered for sale in the gift-shop, this is a place that encourages excitement through all the senses and an environment that entices people to play. This is a complex environment where visitors' experiences are guided by, the artifacts, the architecture, and the creative interactions with staff. Two mechanisms or techniques are the focus of ongoing design decisions as Science World. The exhibits, or *plores* as Gregory would call them (Gregory, 1987), and the stage shows; both are key tools in the activity system design at Science World.

Stage shows take place on a main stage, central among exhibits in a very open and inviting location. Performances last twenty-minutes and occur once each hour. They are based on a set of well-tried theatrical techniques, filled with comedy, suspense, surprise and often a direct link to childhood pleasures. Carefully inserted within these narratives, almost by stealth, the concepts of science become the object of the tales. What stands for surprise is the unexpected or discrepant event; that is counter to intuition about the phenomena. The narrative begins with a principal or phenomena that is common or expected and illustrates an exception. The unexpected result encourages the participant to question or formulate a hypothesis about the observed results. Ice for example, as everyone knows, will float easily on water; however, if you place ice made of water into a bowl of clear alcohol then the ice will sink. Such a demonstration can provoke spirited discussion that when led in the right direction will result in strongly memorable conceptions approximate to relative densities, liquid and solid states and so on. In another show called *The*

Balloon Show, a beaker with a balloon sealing the top was presented to the audience. They were told "the balloon has baking soda in it and there is vinegar in the beaker. What will happen when they are mixed? Excited audience members yelled out a variety of answers. A volunteer shook the baking soda into the vinegar and the balloon expanded exposing a smiley face on the balloon. The performer then offered an explanation of the type of gas that was produced to fill the balloon and went on to describe how early chemists had invented balloons for catching gases during experiments.

The interactive displays and exhibits are another major tool used to achieve the Science World objective; indeed, the exhibits cover well over half of the floor space. In *Eureka Space* there is a particular attention to hands-on interaction. Here the visitor finds: continuous waterways that may be bridged, dammed or canalized using scaled slabs and wedges; guns that shoot forty feet plumes of air at paper targets; and a wind tunnel that while wearing wing section arm bands, visitors can personally experience Bernoulli's aerodynamic lift.

These tools then; the stage shows and interactive exhibits, are the practical reifications of Science World, but it is the deeply enmeshed role they play within a complex of human activity that makes them function in supporting the center's objective. Presentations on stage can create questioning attitudes, exploratory approaches, and a deeper sense of the mysteries of science, but dialogue and facilitation are the keys to understanding those phenomena. Exhibits hold only the potential to support satisfying affective and cognitive experiences. Typical of most science problems, the exhibits don't necessarily have a solution or even a correct mode of play.

To get the most from their experience the coach (or facilitator) is central. While both free-standing exhibits and stage performances can be described with Yager's (1991) four aspects of construction in learning (invitation, exploration, solution and taking action), constructivists regularly reinforce the need for mediation. Good coaches are said to motivate learners to analyze their performance, provide feedback and advice on performance, they demonstrate how to learn, and provoke reflection on and articulation of what was learned (Jonassen, 1998).

The role of facilitation helps mediate the user's experience of the center and the experiences the center has to offer. The benefits of facilitation in exploratory learning environments have been generally accepted since Frank Oppenheimer learnt at the start of the San Francisco Exploratorium, "It is most valuable - indeed essential - to have what he called `Explainers' who are continually available to help, encourage, and offer advice and information" (Gregory, 1987). Indeed, studies show that with facilitation visitors stay longer, can answer questions about exhibits with greater accuracy and underused exhibits can be transformed into fun and interesting experiences. Sighting a number of studies in this vein, Marino and Koke recently conclude (2002) that "In many cases, the investment in interpretive staff would appear to have a strongly positive impact on customer satisfaction."

At Science World there are almost twenty-three full and part-time science facilitators. They are key personnel with particular roles to play in interaction with visitors. Their physical appearance sets them apart from other employees. They wear casual clothing, a Science World t-shirt, and are equipped with radio, cell phones and a clipboard. All Science Facilitators have a tag with their name and *"Ask me!"* clearly printed on it. Facilitators have the most direct reason to interact with visitors as they arrive with families, as members or non-members of the organization, as individuals, school groups and even representatives of funding bodies.

Not surprisingly each community has different expectations of them. New users rarely engage with them (often only to ask for the wash-room). Many regular visitors ask much longer and more demanding questions as they look for new and interesting ways to interact with the exhibits. School groups are themselves driven by outcome goals in the school curriculum and look to the facilitators for connections. Indeed the close relationship between Science World and the school system presents an interesting tension that can be seen in their different objectives and is played out in various operational decisions. Simply put, Science World is directed at affective goals (increasing interest in science) while schools are interested in measurable cognitive gains (even understanding). When school parties visit Science World they use special classrooms on site and in other ways too, their experiences are modified versions of the public experience.

Science Facilitators have a number of responsibilities while on duty; maintaining radio contact for fire safety, controlling access to maintenance rooms, preventing small children from escaping their gallery, locating lost parents, directing patrons to washrooms, providing stage performance schedules, maintaining contraption corner, cleaning glass in fog chambers and relieving the receptionist for lunch and coffee breaks. In addition the full-time facilitators perform on the main stage once an hour through out the day and run forty-five minute school workshops, demonstrations and hands-on activities with school groups. All this is done in addition to answering questions about the exhibits, illustrating phenomena and engaging in dialogue with patrons in supporting the goal of Science World.

> We will provide our customers with a sensational science centre adventure that delivers competitive `fun value' for all ages while stimulating critical thinking and positively influencing attitudes about science and technology.

Our initial description of Science World reveals some of the tensions that arise between the components of action. The clearest of these emerges from the challenge of so many responsibilities of, and demands on the facilitator (tension 1 in Figure 7). The engagement in dialogue around the exhibits competes with the many other activities. Although they do wear a lapel badge labeled "Ask Me!" they also wear the tools of those other roles (cell phones and radios for security roles, clip boards for management purposes as well as watering cans, brooms, etc.) that may communicate a contradictory set of priorities to the visitor. While they go about the tasks described they may seem continuously busy and unavailable. This puts many of the tools in clear contradiction with the goal (taking time from the facilitation role), which is shown as tension 2 in Figure 7. Through various interviews it emerged that these two views of the facilitator role are embodied in different parts of the organization. For accounting purposes they are referred to as customer service employees, while from a curatorial design point of view, they are there to help visitors learn from their experience (we decided to mark this as tension 3 between the roles and the community).

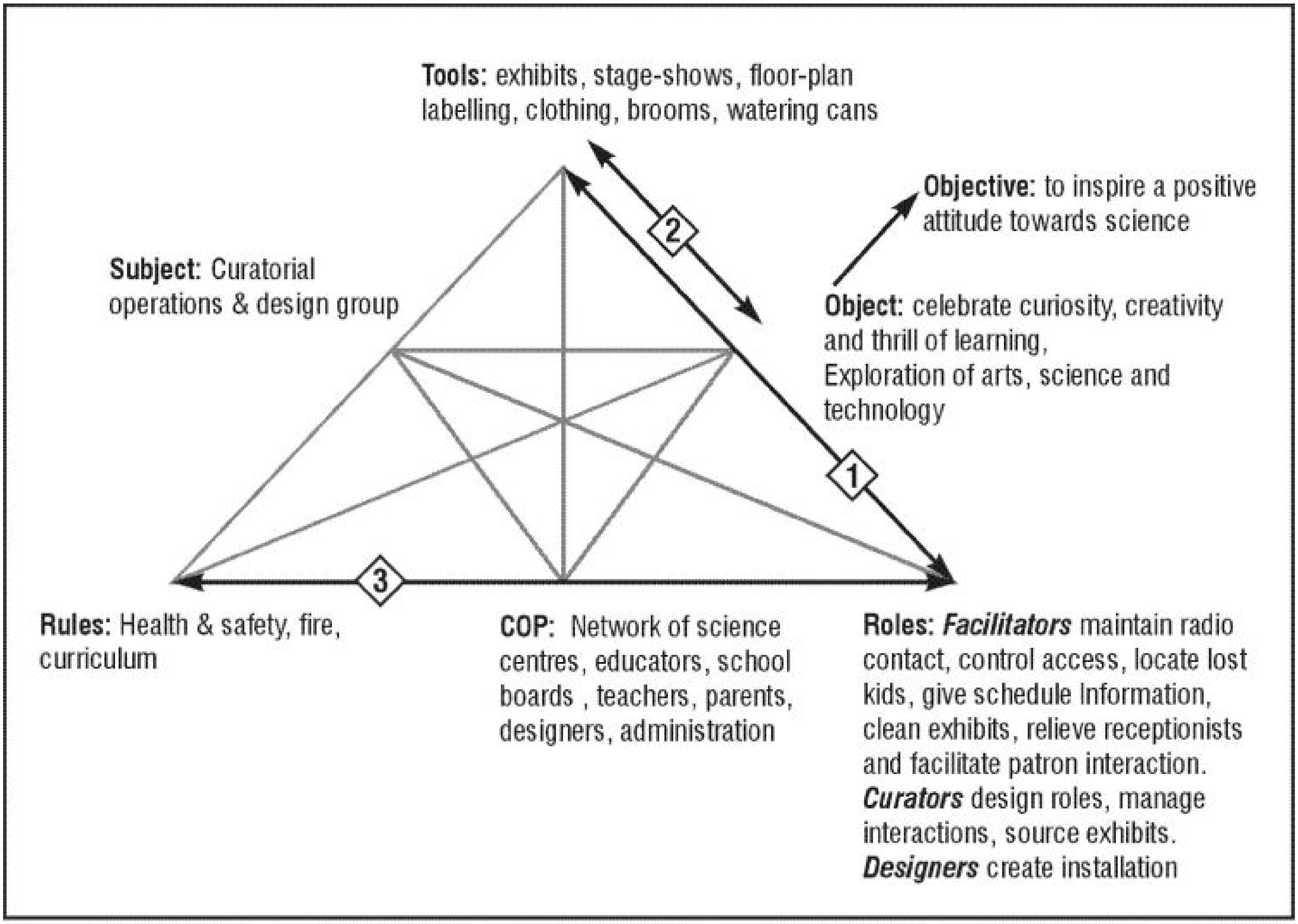

Figure 7. Facilitation at Science World (shifting roles, physical spaces & tools in design).

At this time the curatorial design team is considering ways to enhance the facilitation time and opportunities for patrons, to consider the impressions given by symbols and tools that may be in conflict with this role, and to consider new tools that could build constructive patterns of communication between players. This is not to say that the tasks undertaken by facilitators are inappropriate or much less, unnecessary; the best outcome will begin to take advantage of the customer service interactions initiated by patrons, which often involved non-scientific issues (schedules, washroom locations and so on) using them as an untapped route to enhancing dialogue. A new design currently being considered includes a "station" positioned at the entrance to the Eureka space. This is an important location for orientation to the interactive gallery and a natural place to begin a constructive dialogue. The cocktail-bar height station would be mounted with a computer monitor, Internet access and a specially designed interface to the Eureka Space. The station would be clearly posted and provide a fixed place to find a facilitator and to keep the infrequently used tools associated with other roles (radio for security etc).

Beyond the rationalization of roles the activity analysis also suggested a new emphasis on tools of facilitation (in Oppenheimer's sense). We are currently considering a series of cards with provocative questions that should spark dialogue and support interaction with the exhibits. These would be picked up at Conversation corner. An example card for the new electronic exhibit in Contraption Corner might say the following:

Explore the place where you can make a nose squeal. Hint: our bodies are very good conductors of electricity. Most of our experience with electricity is that it's dangerous. The exhibit shows how small amounts of electricity can be sent through our bodies safely.

We are exploring models for the construction of introductory speech acts designed to stimulate dialogue around artifacts. These design opportunities arose specifically from taking an activity theoretical look at the component parts of the activity systems enacted around the Science World mission. In looking at the roles, tools, tensions and contradictions of the current system we were able to quite clearly see how each component part was either aligned or in tension with the object of activity. The new design options will be implemented in a prototype form and tested for adoption across the space. The methods are also likely to be used again in other areas of the operation particularly in embedding practices that we hope with more naturally lead to an ongoing exhibit quality awarenes.

Dissussion and Conclusion

Earlier we claimed this work would somehow help explain how criticisms of AT in learning technology design did not reflect its real potential to contribute to improved learning technologies. Each of the examples; the evaluation of SPLASH, the design and implementation of a K-12 virtual school, and redesigning aspects of a public interactive Science Centre, each demonstrate positive but characteristically different value in the theory applied.

In the evaluation of SPLASH we used AT to show how tools sometimes create tensions within an activity system by failing to support each player in the community of practice. Tools with functions shared among different roles need to be designed to support each role _ not necessarily by designing a separate interface for each role user, but more likely by compromising the trade-offs of usability and utility to form a preferred common interface. We discussed the negotiation process that is likely to occur in the appropriation of such new tools into the activity system.

In the virtual school example we showed how AT provides structure and focus to discussions among an implementation team. Where once there was an overwhelming set of tasks, the team is now better able to focus on points of concern while maintaining and sharing a common view of the project goals. AT has heuristic value in the absence of pre-established formula and guidelines for how to proceed into this new territory. It does not offer prescriptive tools to guide the implementation and development process. Rather, it is an effective vehicle for identifying where breakdowns occur and provides a common language for opening constructive dialogue. Perhaps its greatest strength lies in its adaptability to dynamic contexts where its analytic lens can be refocused when unanticipated disruptions emerge.

The studies at Science World used AT and led to a re-conception of the role, physical layout, and positioning of tools associated with the Science Facilitator. In order to further promote an open invitation to patrons to communicate with facilitators, their position in the building was changed, their outward presentation of role to the patrons were changed by concealing tools of roles that are in competition with the science discovery dialogue.

We have described use of activity theory in three different ways:

1. To demonstrate evaluation of an innovative tool within an ecologically reasonable setting and to develop design requirements for a new version of the tool. In this case the theory acts as a design constraint (a forcing function) that requires we consider the roles of those involved in the system not just the most obvious user.
2. As a tool for managing interaction in a cooperative design team. Used in real-time as a check against

good practice and as a model for recording events over time. The tool redistributes effort in a way that prevents us from neglecting clearly important aspects of participation.
3. To outline the complete set of opportunities for re-thinking the redesign the physical environment of interaction, the roles and distribution of work in a museum. In each case AT forced a consideration of aspects in design that transformed the problem from one of reduction and cognitive analysis to one of social and technical organisation.

We believe the limitations of AT reported in the studies outlined at the beginning of this paper are a function of several factors, including a misplaced and outmoded goal to formulate widespread routine step-wise design processes and a focus in evaluation on the summative and judgmental instead of on the formative improvement goal. The role that activity theory can play is a crucial one in design in that is able to consider the current context of the multiplayer group and their current distribution of roles and activities. In contrast to either instructional system design approaches (Dick & Cary, 1990) or software engineering approaches such as UML (e.g., Booch, Rumbaugh, & Jacobson, 1999), in which users are more likely to reduce the account of activity so that the situation and historical preconditions in which development is planned are hardly considered at all, activity theory provides tools for higher level analysis as well as guidance in design. In AT the main impact for design lies in identifying contradictions and tensions in systems of people, roles and tools. These include (a) conflicting, misunderstood or contradictory goals, (b) misaligned distribution of labour and technology, (c) unsuitable tools - too restrictive for purpose, maybe too flexible (not enough leverage), too difficult to master, (d) inopportune cultural conditions or organizational structures, and (e) cultural practices without incentive.

Indeed, in answer to the call for a general design prescription from activity theory, we would refer to some general principles that have for us emerged through using activity theory in design. The need for balance in organizational and systems design between structure and spontaneity (Brown & Duguid, 1991), between participation and reification (Wenger, 1999), and in the recognition that categorization in the design process (ontology formation), has hegemonic and therefore operational impact on practice (Suchman, 1993). The convergence of these themes leads us to adopt a general design goal - implicit in activity theory when taken seriously - to create environments that, do a good job at supporting the enterprise goals for organizations, but regard equally highly the prerogative of professionals to design and enact there own practice.

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Endnotes

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